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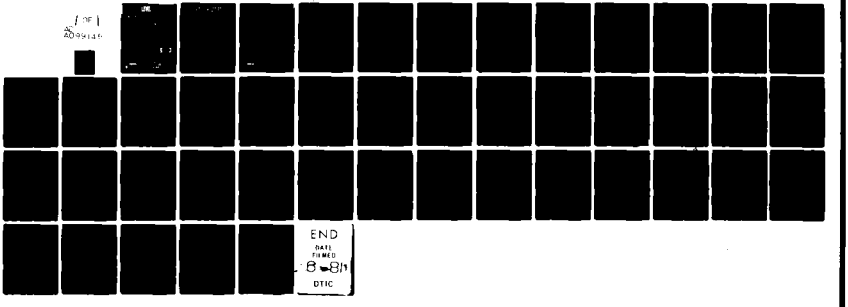

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A RAND NOTE

SUBJECTIVE MEASUREMENT OF TACTICAL AIR COMMAND AND CONTROL--VOL. II: THE INITIAL REPRESENTATION

Monti Callero, Willard Naslund,
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The authors have developed the Subjective Transfer Function (STF) approach for evaluating complex systems and are applying it to the evaluation of tactical air command and control. The first step in applying the STF approach is to formulate an initial hierarchical representation of the problem domain. This representation reflects initial hypotheses about what are the important components of the domain and how they are interrelated. It provides the framework for testing these hypotheses by measuring professional judgments. The note displays the initial representation formulated for the command and control evaluation being conducted. Other volumes in this series will describe the conduct and results of the evaluation. (37pp) (Author) (Ref.)

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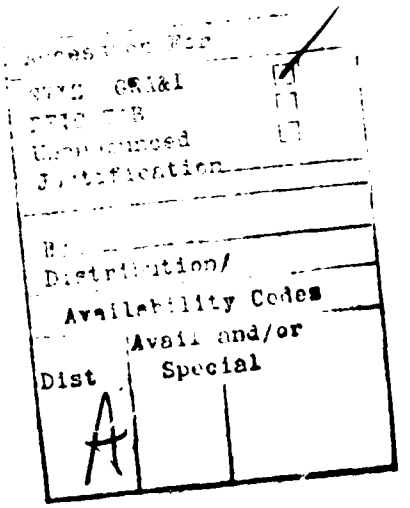
PREFACE

This is the second in a series of Rand Notes describing the application of a newly formulated subjective measurement method to the evaluation of tactical air command and control. It describes the initial hierarchical representation of the evaluation problem. Other Notes in the series are N-1671/1-AF, which provides an overview of command and control evaluation and the subjective measurement method and details a conflict environment associated with the evaluation problem, and N-1671/3-AF, which reports the results of preliminary investigations. Further Notes will be added as the evaluation proceeds. The research is being done under the Project AIR FORCE-sponsored project "Tactical Air Command and Control."



CONTENTS

FIGURES

I. INTRODUCTION

We are conducting a subjective analysis of the impact of battlefield intelligence on the ability of tactical air command and control to effectively employ tactical air forces against enemy second echelon ground forces. The analysis utilizes our newly formulated Subjective Transfer Function (STF) approach to complex systems analysis and will serve to demonstrate and refine it.[1]

In Volume I (Callero, Naslund, and Veit, 1981) of this series of Notes, we defined the evaluation problem, described an exemplary conflict environment, and explained the subjective transfer function approach. The first step in applying the subjective transfer function approach is to construct an initial representation of the problem domain. This representation reflects initial hypotheses about what are the important components of the domain and how they are interrelated. It provides the framework for testing these hypotheses by measuring professional judgments.

In this Note we present an initial representation for the specific problem of interest. In the remainder of this section we review the problem and its interpretation in subjective measurement terms, and review the STF approach to formulating an initial representation.

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[1] For a detailed description of the subjective transfer function approach, see Veit and Callero (1981). An overview is given in Callero, Naslund, and Veit (1981).

PROBLEM REVIEW

To briefly review, the problem of interest [2] stems from the potential provided by developing reconnaissance and surveillance systems to significantly increase the amount and improve the quality of battlefield intelligence. Our analysis task is to evaluate tactical air command and control capability to effectively employ tactical air against targets [3] in the enemy second echelon area given different levels of information about the enemy second echelon forces. Information levels of interest range from what currently can be expected to what can be expected under enhanced collection capabilities.

A Korean-like theater conflict is to be used as a backdrop for the evaluation. Second echelon forces are considered to be reinforcing forces (not in direct contact with friendly forces) but which are in a position to directly affect friendly forces. The second echelon area is considered to range from 10 to 100 kilometers from the immediate area of ground force contact.

In applying subjective measurement to this evaluation problem, we seek to accurately determine military professionals' judgments about the effects that different levels of information about enemy second echelon forces would have on the effectiveness of the employment of tactical air against those forces. Following the evaluation concepts set forth in Volume I, effective employment of tactical air will be considered in terms of its influence on the outcome of the land battle.

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[2] The problem was defined in conjunction with Air Force personnel from the Tactical Air Command, the Tactical Air Forces Interoperability Group (TAFIG), and Headquarters, Air Force, Studies and Analysis.

[3] We define target as "an object of military value."

INITIAL REPRESENTATION FORMULATION REVIEW

The main points from the discussion in Volume I on formulation of an initial representation of the problem domain are briefly reviewed below.

The representation must be constructed so as to relate system components of specific interest to system outcomes of specific interest. In the problem defined above, components of specific interest are those related to information about enemy second echelon forces. Outcomes of specific interest are (1) the ability of the command and control system to perform its functions, (2) the performance of tactical air operations, and (3) the outcome of the land battle.

System components are referred to as "primitive" if no other components in the representation are hypothesized to affect them. Primitive components provide the basis for defining specific systems and assessing what effect changes to a system have on achieving desired outcomes. Non-primitive components are hypothesized to be affected by other components. Hence, non-primitive components reflect system outcomes, since in any particular system, their quality, condition, or capability results from the effects of system components.

An initial system representation develops from the hypotheses of "experts" about what system components affect the important system outcomes. The numerous system hypotheses are represented by an hierarchical structure composed of components linked together in "experimental units." Each experimental unit links a non-primitive component, which represents an hypothesized system outcome, with three to five components (either primitive or non-primitive) that are hypothesized to directly affect that outcome.

Components that are hypothesized to directly affect a system outcome are the independent variables in experiments investigating their effects on that outcome. For each of these components we must determine four or five descriptive levels spanning the "best" to "worst" expected quality, condition, or capability relevant to the component. These descriptive levels are manipulated in experimental designs that allow tests of main and interaction effects of the components on judgments, as well as tests of hypothesized models (referred to as subjective transfer functions for reasons described in Veit and Callero, 1981) that specify the nature of these effects.

The initial system representation is only a starting point. The system representation evolves iteratively as the hypotheses are tested. Inclusion or exclusion of hypothesized system components depends on their meaningfulness to the respondent population and their empirical effects on judged outcomes. When components initially selected to define a system do not affect judgments of hypothesized outcomes (determined through statistical analyses), they are eliminated from the representation and, possibly, new components are tested. The final complex system representation emerges only after empirical support has been obtained for the effects of all hypothesized components on judged outcomes.

II. THE INITIAL HIERARCHICAL REPRESENTATION

Using the evaluation problem description and the representation concepts discussed above, we have formulated an initial representation of the evaluation problem domain. In this section we display and describe the overall representation. In Section III we detail the definitions and description levels for each component.

The goal in formulating this initial representation is to relate information available to the tactical air command and control system pertaining to enemy second echelon forces and other targets in the second echelon area to the influence of tactical air on the outcome of a land battle. Furthermore, included in that relationship must be the important outcomes affected by that information which are relevant to the command and control process and the employment of tactical air against the second echelon targets.

OVERALL REPRESENTATION

The overall hierarchical representation is shown in the 3 panels of Fig. 1. To facilitate discussion, we have labeled the hierarchical tiers input, element, function, and employment. The experimental units are numbered on the link between the non-primitive component (the outcome) and the components hypothesized to affect it.

The three panels result from our hypothesis reflected in experimental unit 1 that the land battle is affected by employing tactical air to perform three distinct tactical air actions--engage fixed targets (panel A), engage stationary force elements (panel B), and

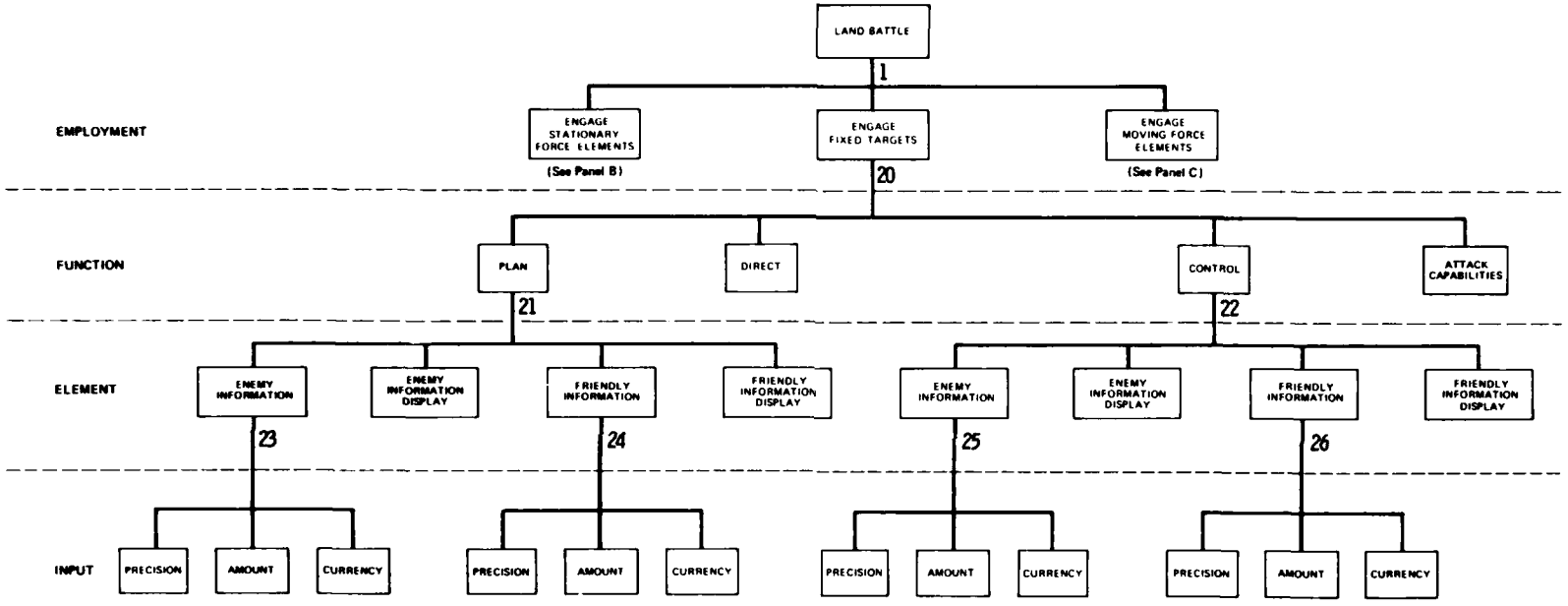

Fig. 1--Panel A--Representation of tactical air command and control and force employment system: fixed targets

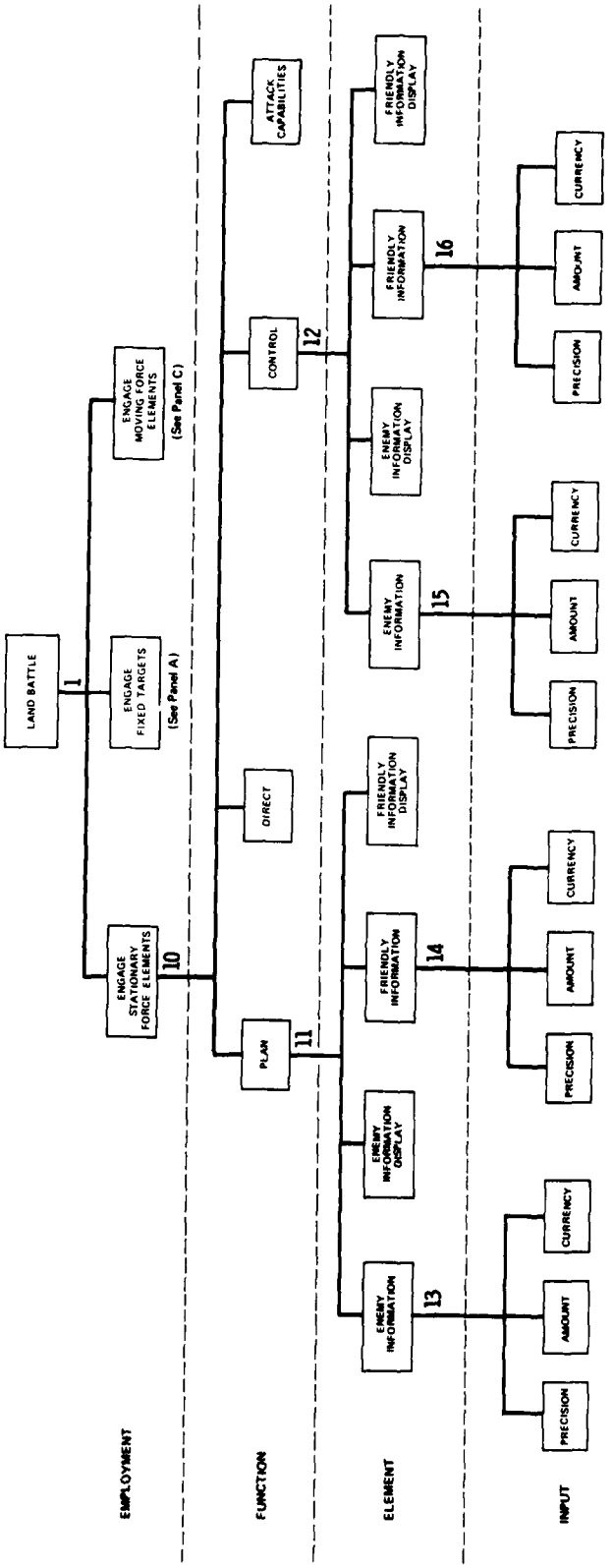

Fig. 1--Panel B--Representation of tactical air command and control and force employment system: stationary force elements

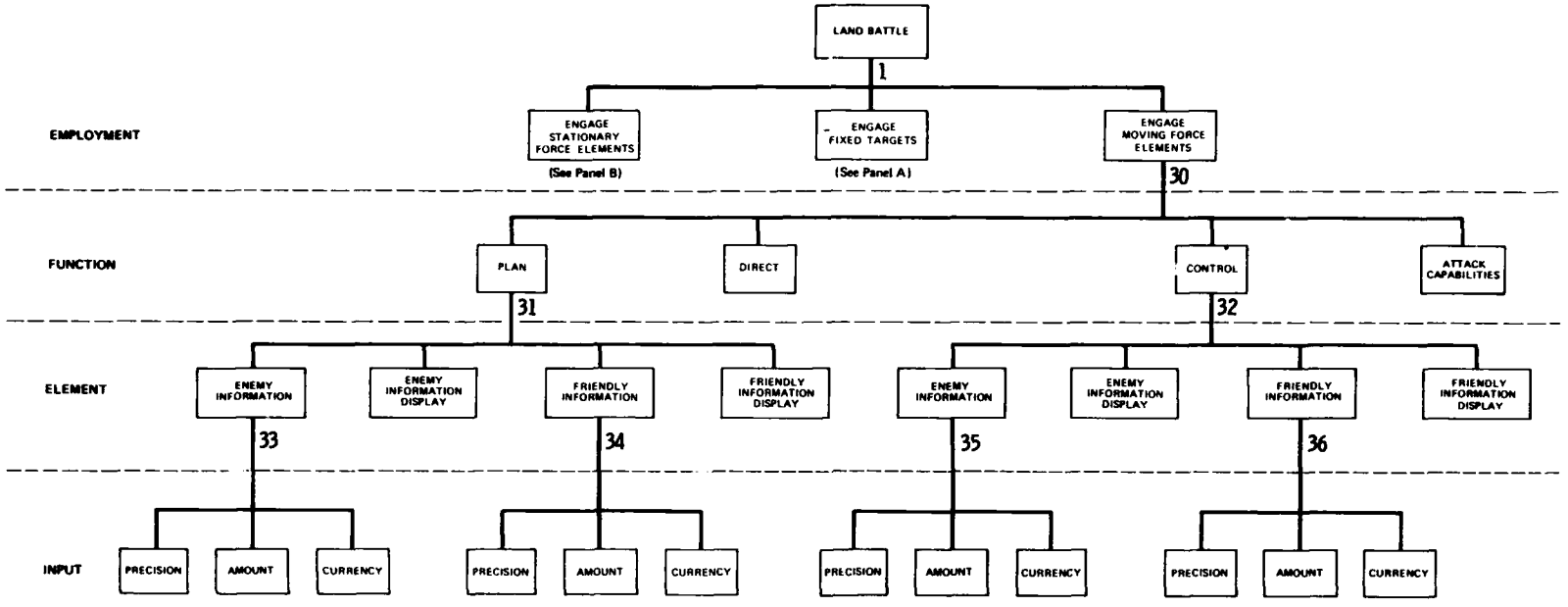

Fig. 1--Panel C--Representation of tactical air command and control and force employment system: moving force elements

engage moving force elements (panel C). Each of these tactical air action components at the employment tier is hypothesized in experimental units 20 (panel A), 10 (panel B) and 30 (panel C), respectively, to be affected by the command and control process functions of plan, direct and control, and the attack capabilities of the available tactical air forces. The remaining experimental units follow the same concept of reflecting causal hypotheses, and the reader is left to observe them directly from the Fig. 1 panels.

Each of the panels has the same general hypothesized representation structure below the employment tier. However, it must be recognized that, although the names of components at different places in the representation are the same, the components generally will refer to markedly different entities, concepts, or actions. They must be considered only in the context of their position in the representation. For example, attack capability against fixed targets generally results from considerably different weapon system configurations and tactics than does attack capability against moving force elements. Similarly at the input tier in panel A, the Precision, Amount, and Currency components hypothesized to affect enemy information in experimental unit 23 are not at all the same as the components with the same name in experimental unit 24. They stem from entirely different information collection systems and refer to entirely different items of information. These differences will become more apparent from the more detailed discussion of the components in Section III.

PRIMITIVE COMPONENTS TO DEFINE SYSTEMS

In Volume I [1] we describe how particular command and control systems to be evaluated are defined by specifying descriptive levels for each of the primitive components in the representation. The initial representation displayed contains 54 primitive components with which to define a system. They are the 36 components at the input tier; the 12 components for Enemy Information Display and Friendly Information Display at the element tier; and the six components for Direct and Attack Capability at the function tier.

Descriptive levels of primitive components can reflect actual or postulated real world conditions to describe a system. Levels reflecting actual conditions would be used to evaluate an existing system or to provide a basis of comparison for new (non-existent) systems that can be described by postulated conditions. This ability to reflect postulated conditions permits us to determine conditions that are perceived to produce desired effects. Once the subjective transfer functions (which specify the relationships among the components) are determined, system outcomes can be predicted for any combination of descriptive levels of the primitive components. Hence, the level of one or more components can be systematically changed to investigate the perceived effects the changes have on system outcomes and to seek out levels which produce desired effects. Or, stated another way, to seek out postulated systems which produce desired results.

For example, the Attack Capability components in the employment tier permit investigation of the effect on the predicted land battle

[1] Callero, Naslund, and Veit (1981), pp. 24-26.

outcome of different allocations of attack capability among the three target categories. Since the levels of the Attack Capability components directly reflect the allocation, different allocations would be investigated by specifying different feasible combinations of levels (i.e., ones that did not exceed the overall available attack capability) for the three Attack Capability components. A total attack capability would be reflected in the tactical air order of battle for a particular scenario or conflict situation, so allocation is an important operational decision which could be aided by this investigation. Other examples which could be of interest are Enemy Information Display components (what information processing and display systems are perceived to abet the decisionmaking processes and how they affect the utility and cost effectiveness of improved information collection systems), and of course, the Precision, Amount, and Currency components related to enemy information (how different levels of these components affect system outcomes), which are the specific focus of the investigation.

It may be necessary to conduct special experiments below the input tier in order to reflect a particular reconnaissance or surveillance system. For example, a descriptive level for the Currency components linked to the Enemy Information components may not be possible to determine directly from the collection system specifications. However, the currency of the information reported to the command and control system by that collection system may be definable in terms of how frequently the battlefield is observed (a function of how many collection devices there are) and how long it takes to process the

information and transmit it to the command and control system (a function of the system's processing and communications technology). In this case, an experimental unit would be added at each of the appropriate Currency components which would link Currency to a component reflecting the frequency of observation and component reflecting the reporting time interval. These new experimental units would then be tested in the same manner as the others.[2]

We next look at the experimental units and components in detail.

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[2] An illustration of such an excursion is described in Volume III (Veit, Rose, and Callero, 1981), Section V.

III. COMPONENT DEFINITIONS AND DESCRIPTIVE LEVELS

In this section we provide detailed definitions and descriptive levels for each of the components in the initial representation. Following a discussion of experimental unit 1, the information is presented in figures sequentially by experimental unit numbers.

Recall from Section I that for each component that is hypothesized to directly affect a system outcome we must determine four or five descriptive levels spanning the "best" to "worst" expected quality, condition, or capability relevant to the component. We have selected high and low descriptive levels for the components reflecting perfect characteristics and completely inadequate characteristics, respectively. This does not reflect a view that either of those levels are to be expected. They were selected to provide a representation applicable to a wide range of potential systems as well as to the current systems.

EXPERIMENTAL UNIT 1

Experimental unit 1 represents the hypothesis that the outcome of the Land Battle is affected by the employment of tactical air in the second echelon area to engage stationary enemy force elements, to engage fixed targets, and to engage moving enemy force elements, and that the influence of tactical air on the outcome can be perceived by considering these three tactical air actions. The effects the tactical air actions are hypothesized to have on the outcome of the land battle range from a

best of

> Tactical air actions deny enemy second echelon force movement toward the area of conflict and preclude them from affecting the outcome of the land battle, thereby assuring that the friendly forces win.

to a worst of

> Tactical air actions insignificantly affect the number and rates of movement of enemy second echelon forces toward the area of conflict and their contribution to the land battle, thereby having essentially no influence on the outcome.

Experimental unit 1 is depicted in Fig. 2 with the definitions and the descriptive levels of the independent variables (components).

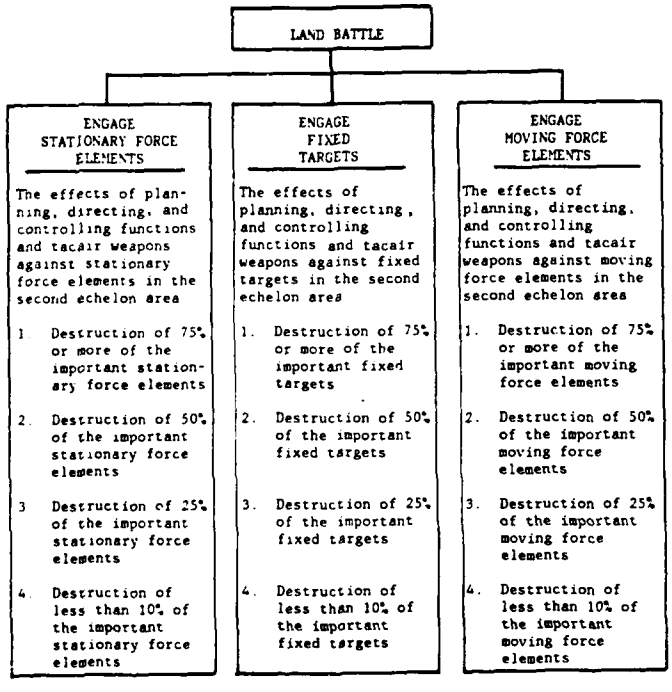


Fig. 2--Experimental unit 1

THE OTHER EXPERIMENTAL UNITS

In this section the other experimental units shown in panels A, B and C of Fig. 1 are displayed in a series of figures. In each figure, dashed boxes and lines indicate the lineage of the experimental unit and all definitions and descriptions are relevant to that lineage. For example, in Fig. 4 the definition of the Plan component applies to the engagement of stationary force elements in influencing the outcome of the land battle. But in Fig. 11 the definition (in the same words) applies to the engagement of fixed targets in influencing the outcome of the land battle. Similarly, the definitions and descriptive levels of the independent variables (components) in these figures apply to planning for engaging stationary force elements and planning for engaging fixed targets, respectively.

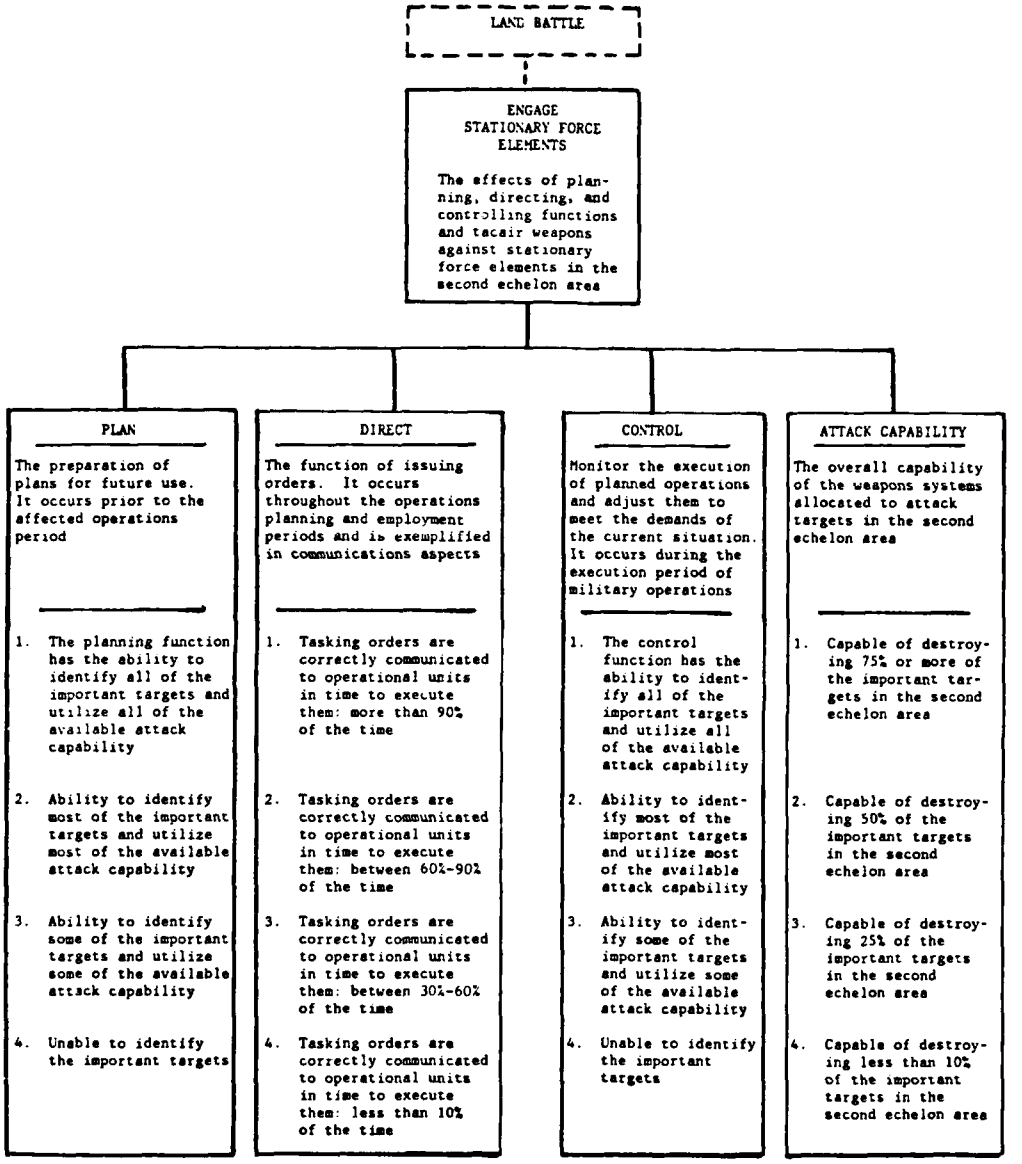


Fig. 3--Experimental Unit 10

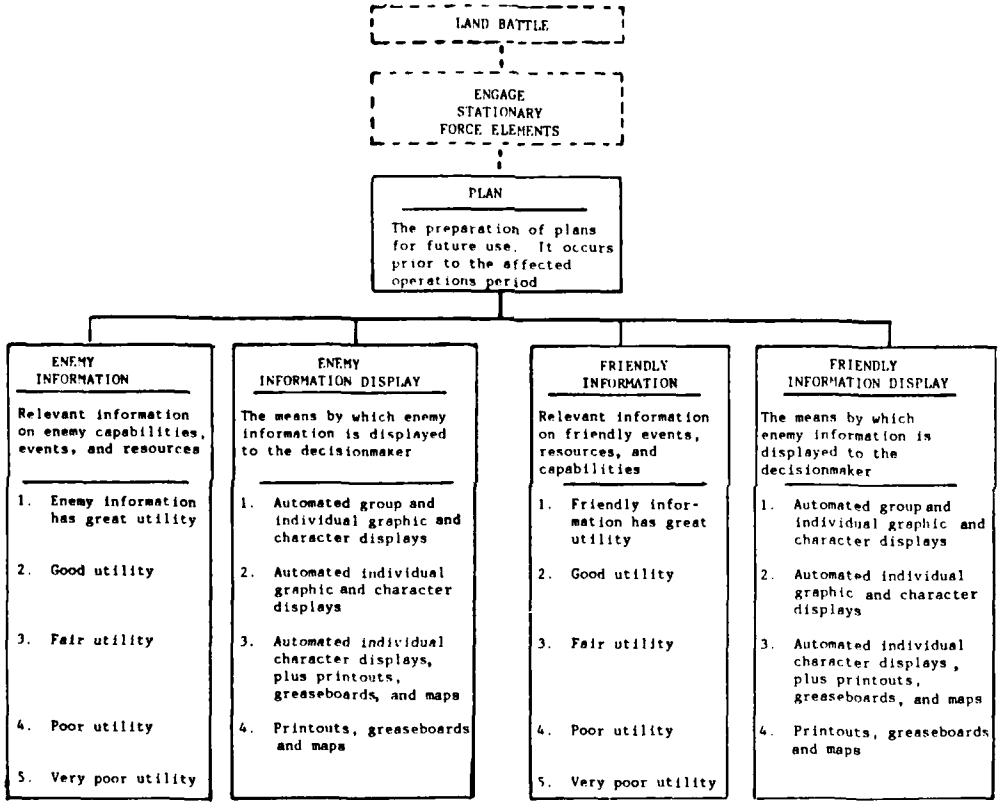
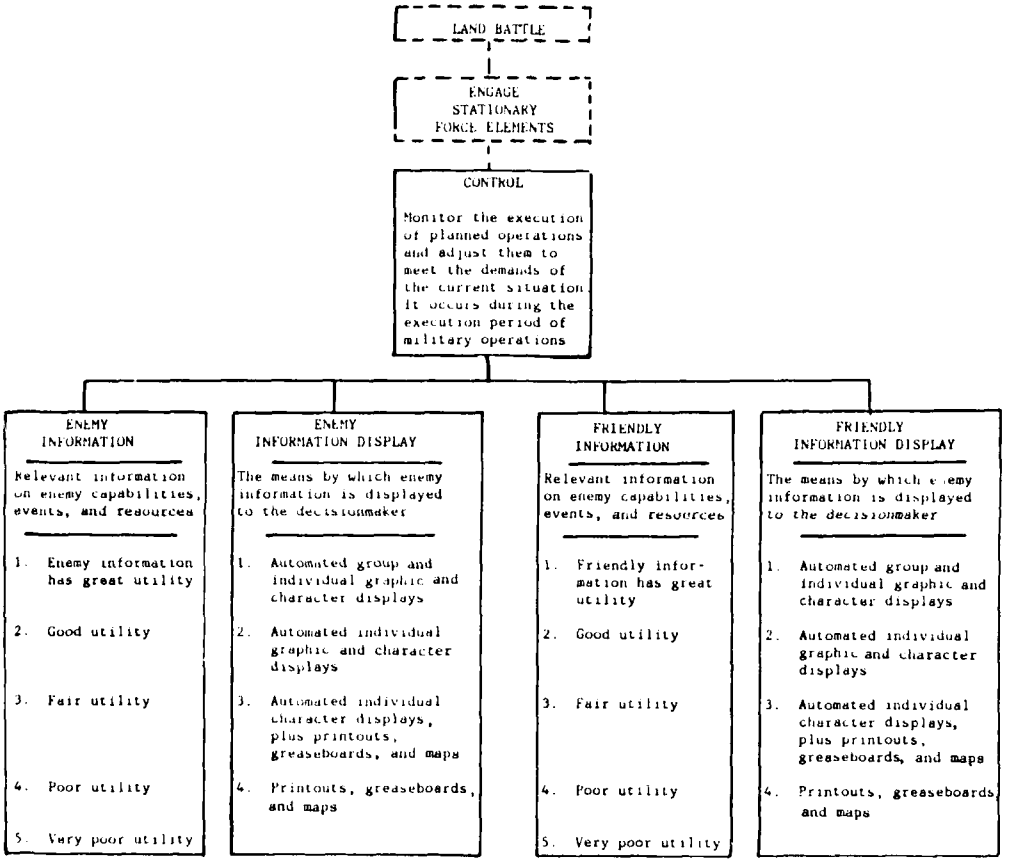


Fig. 4--Experimental Unit 11



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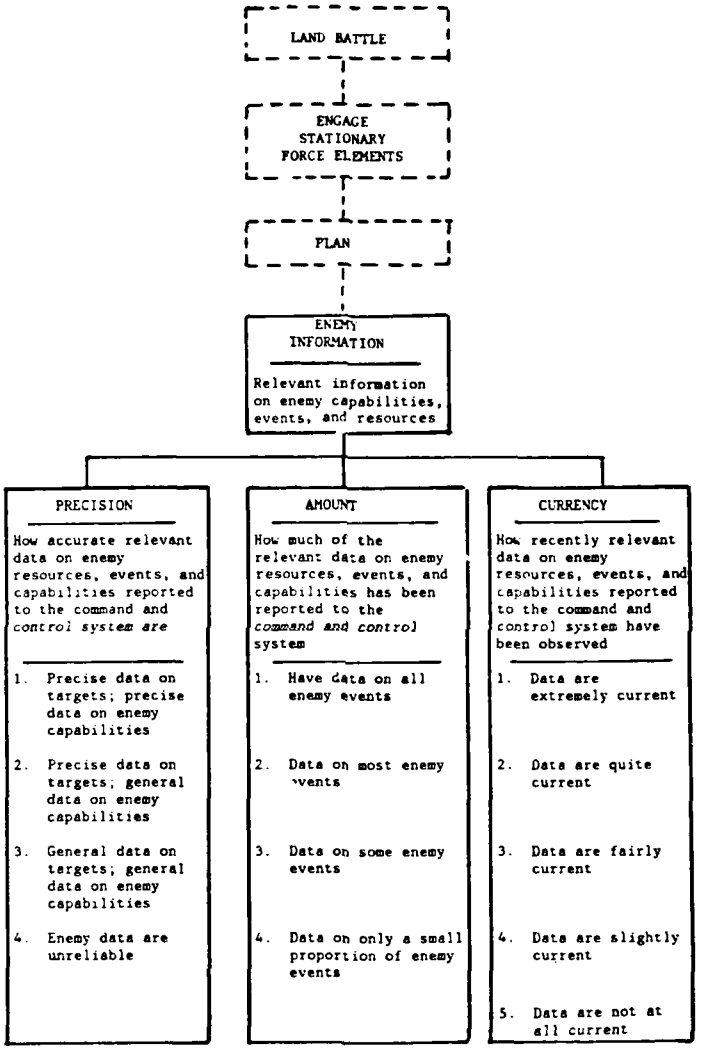


Fig. 6--Experimental Unit 13

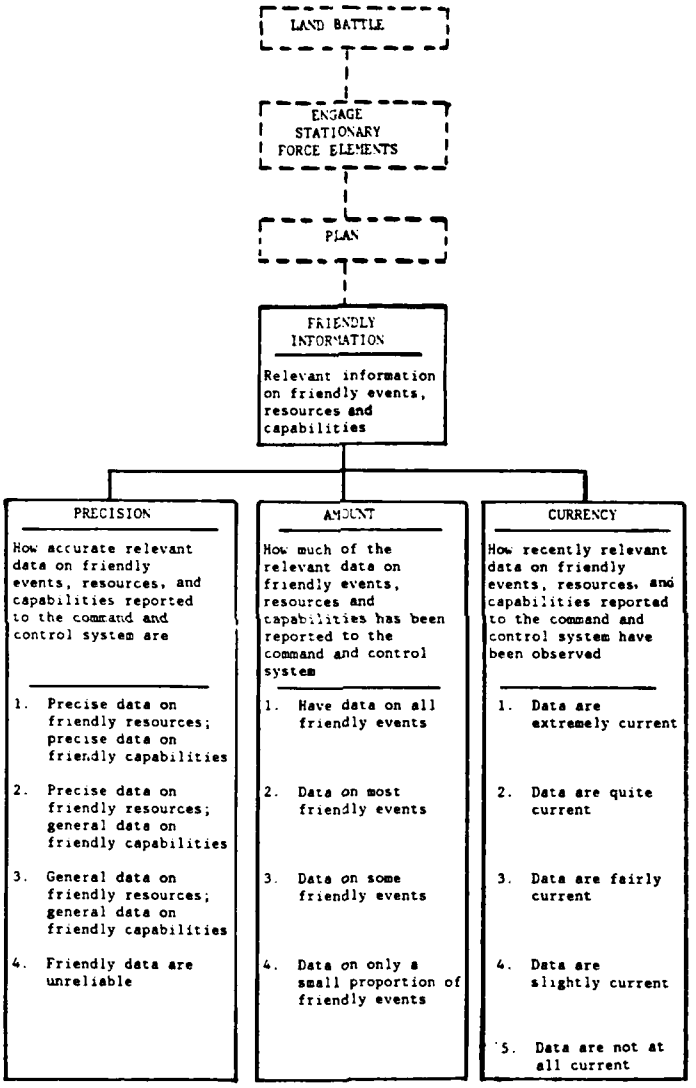
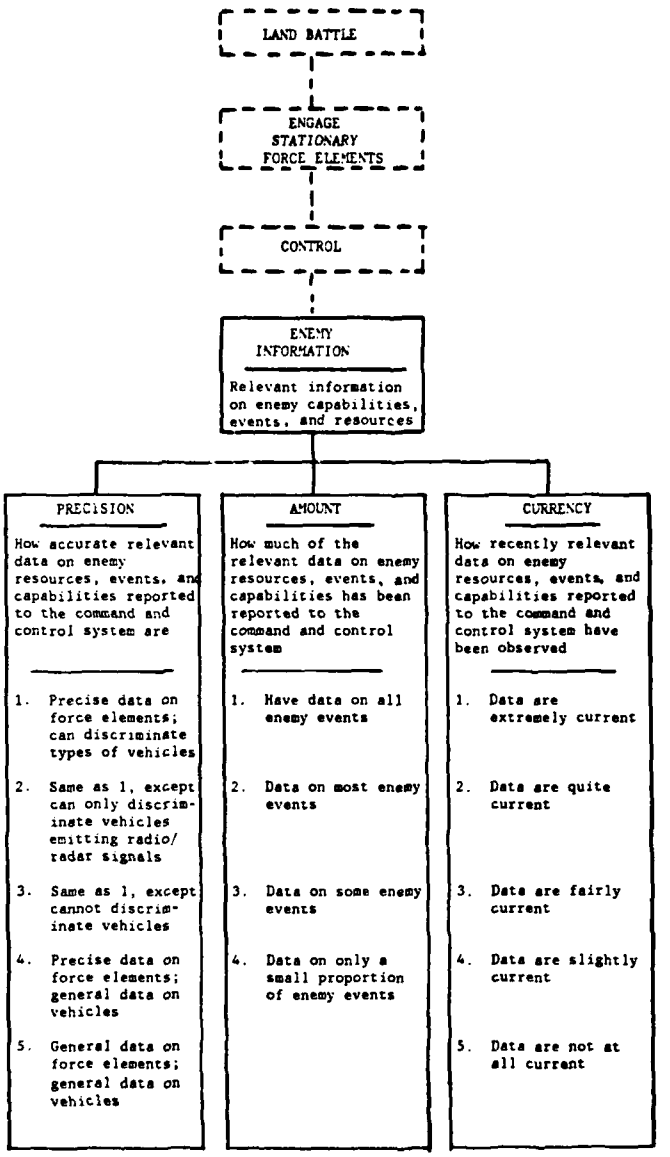


Fig. 7--Experimental Unit 14



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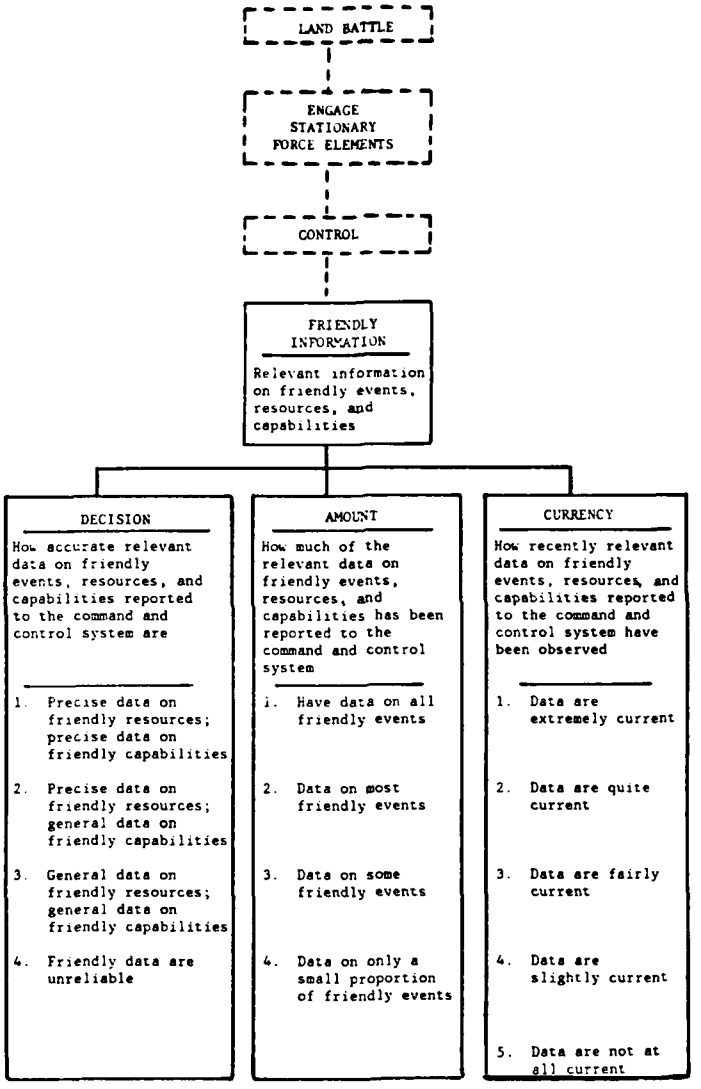
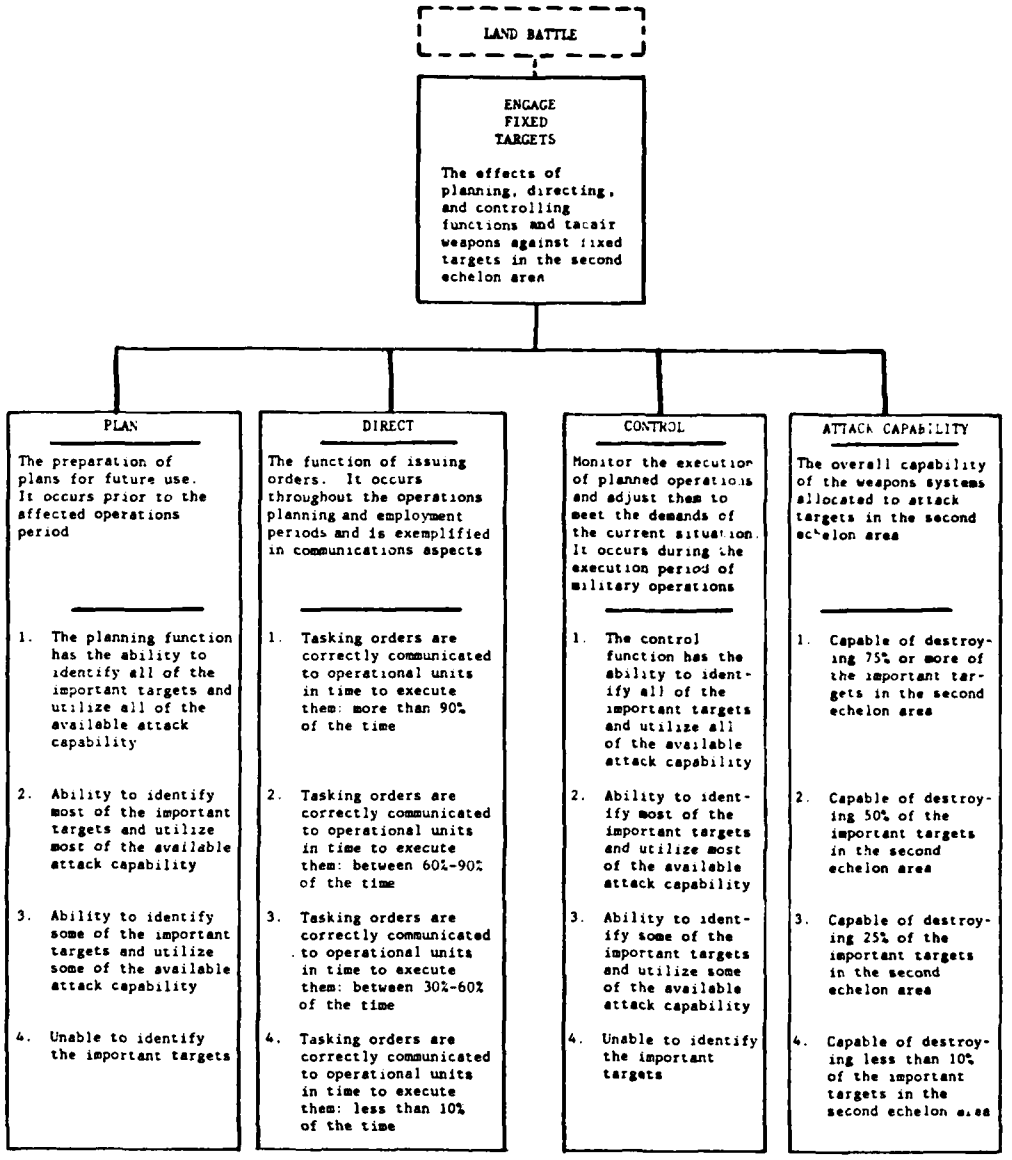


Fig. 9--Experimental Unit 16



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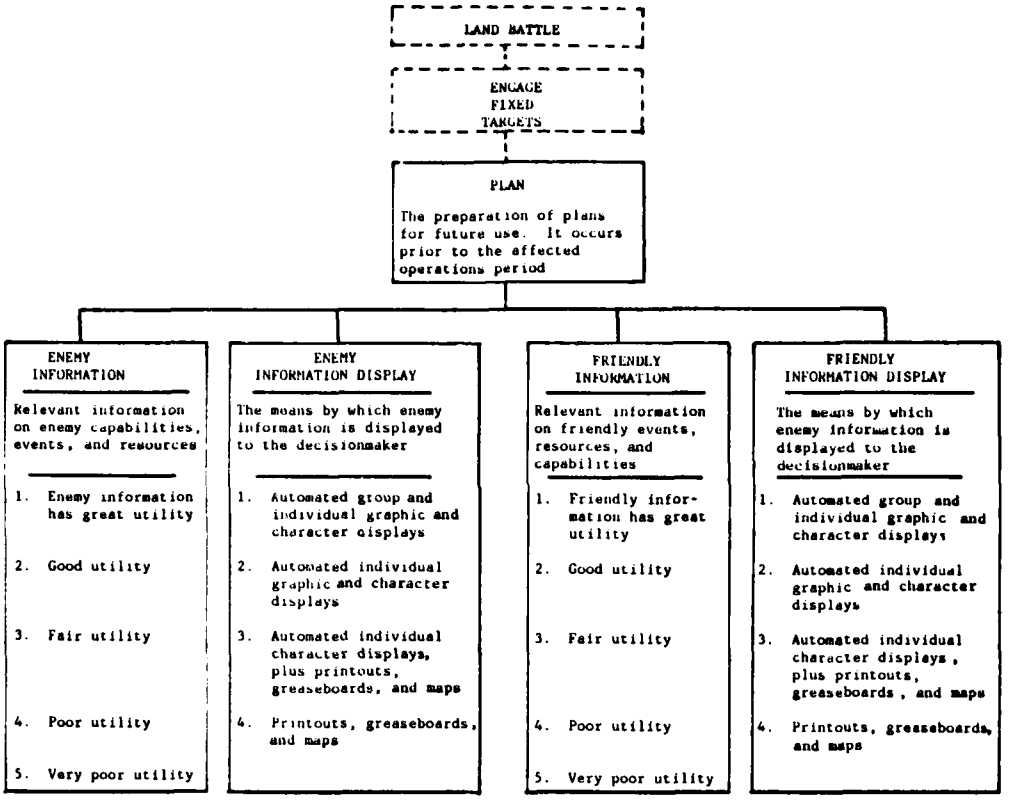
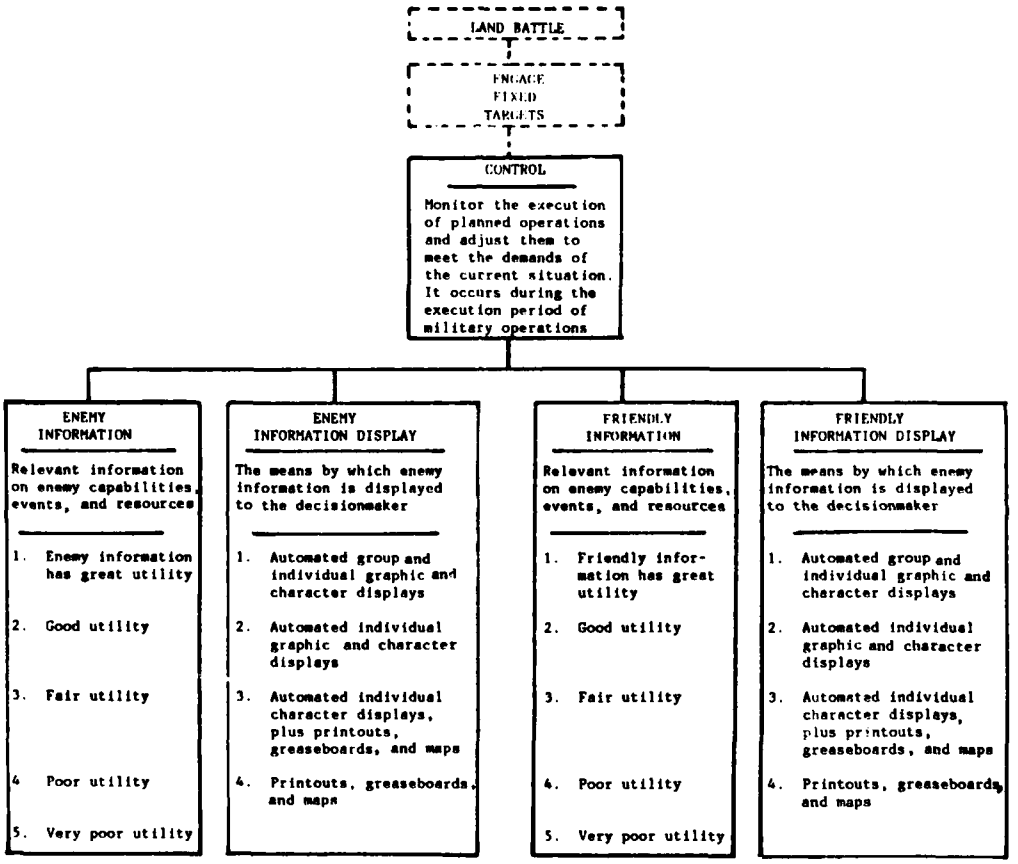


Fig. 11--Experimental Unit 21



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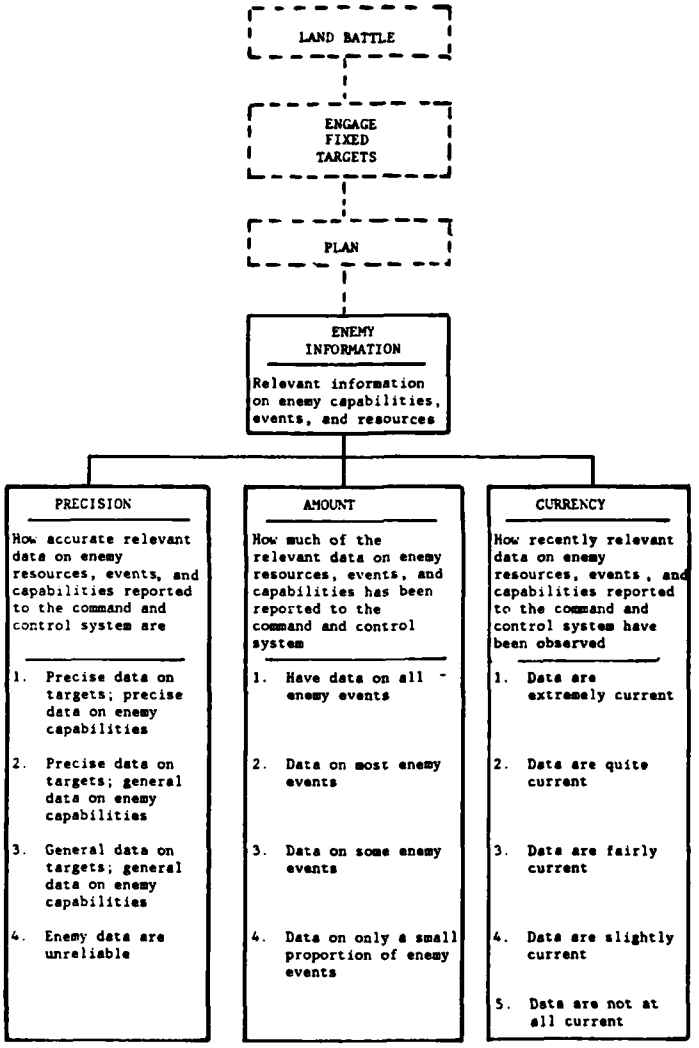

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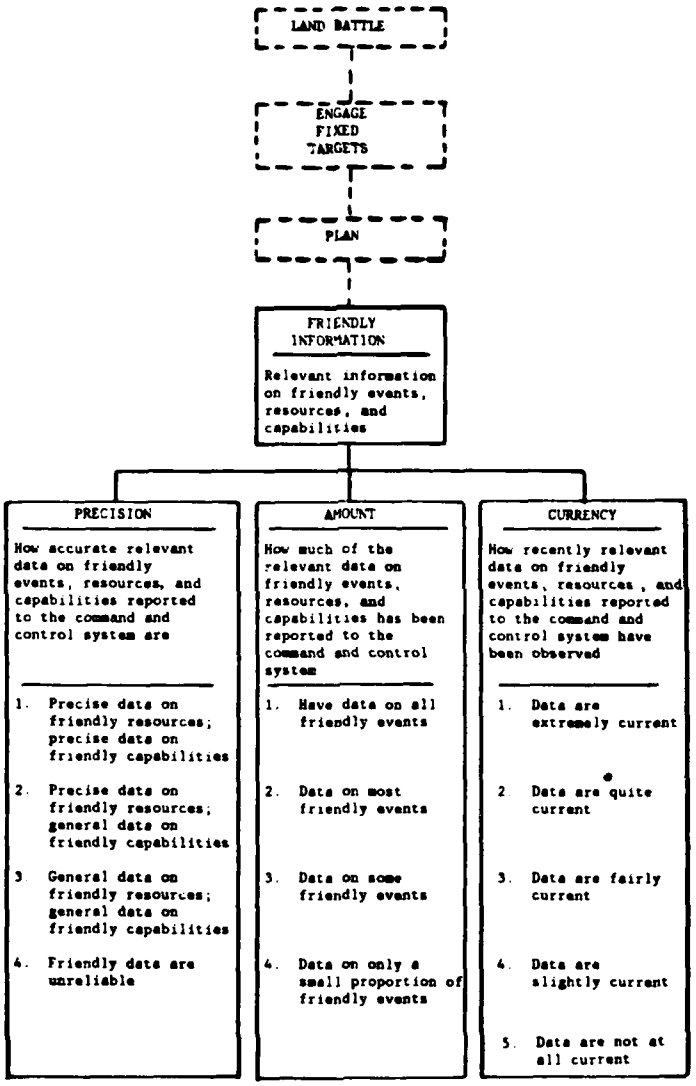
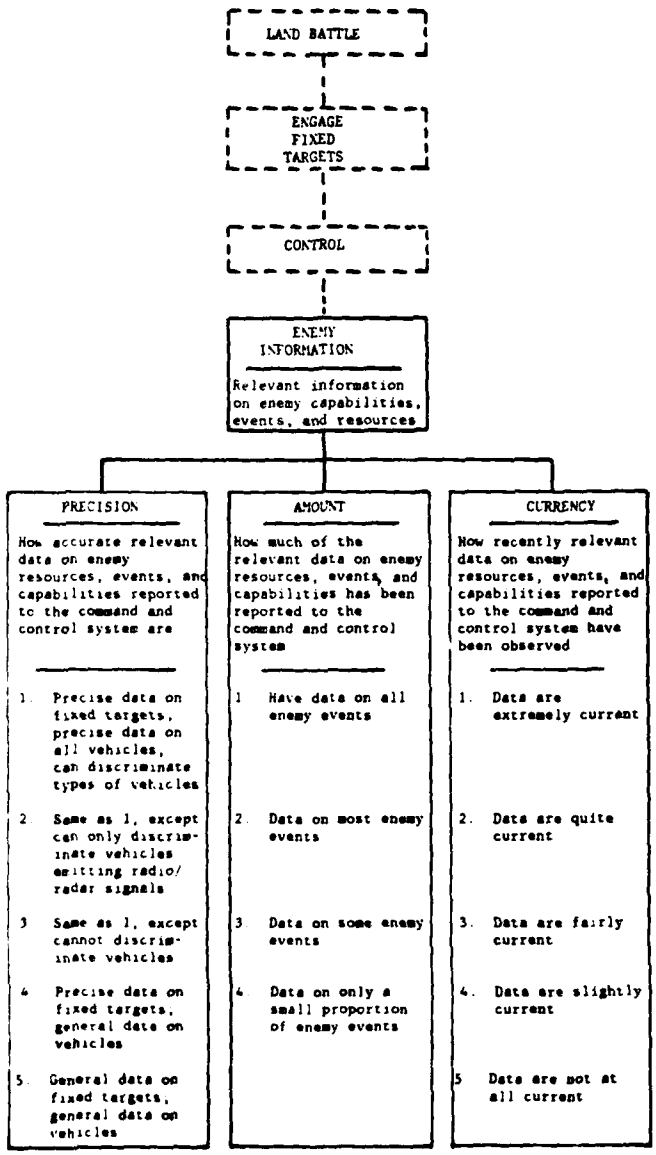


Fig. 14--Experimental Unit 24



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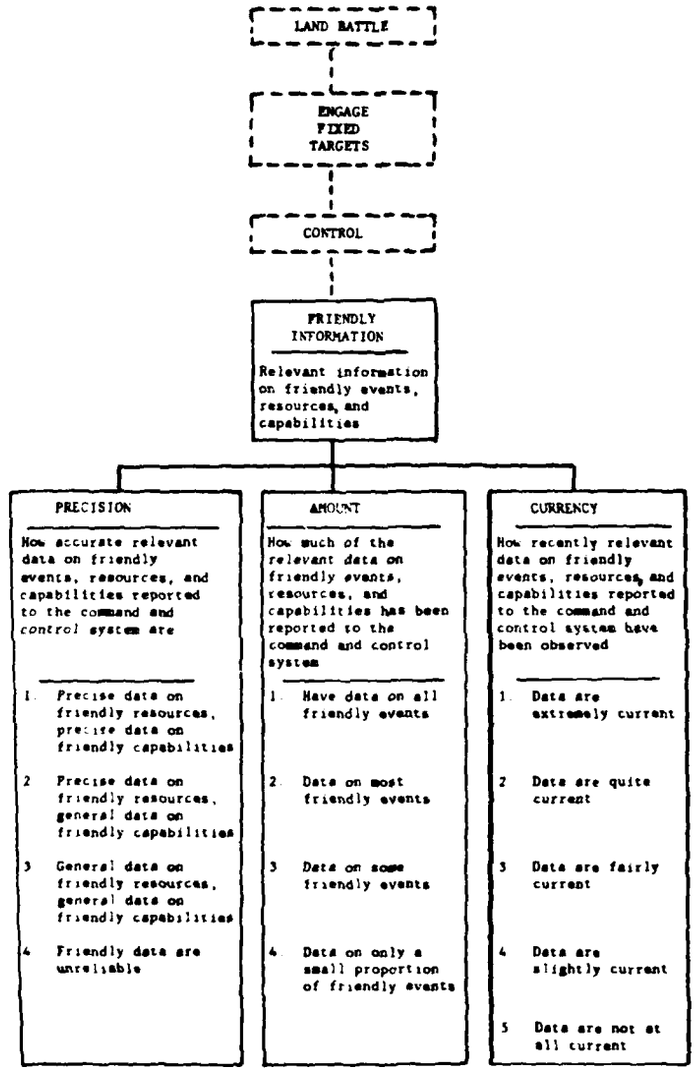
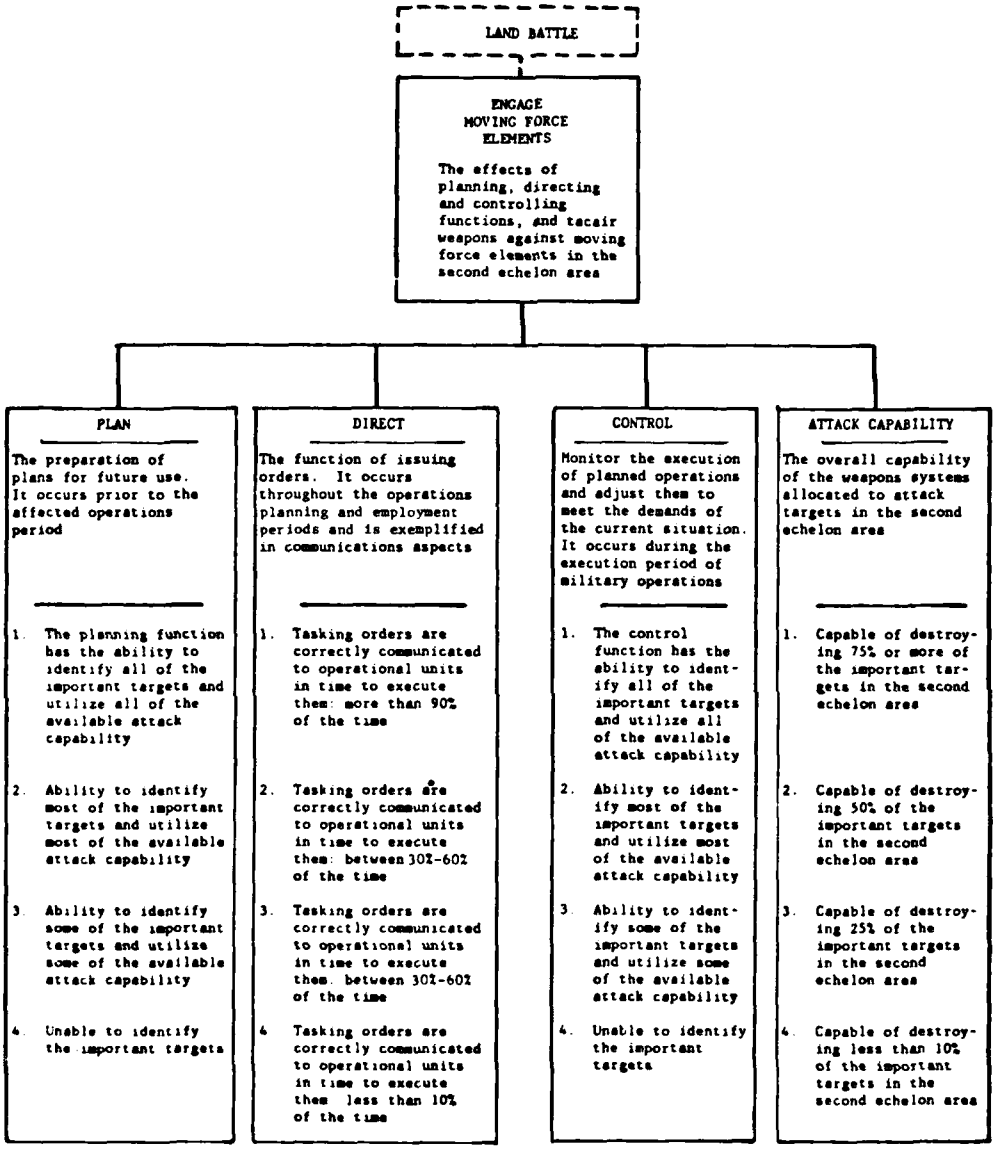


Fig. 16--Experimental Unit 26



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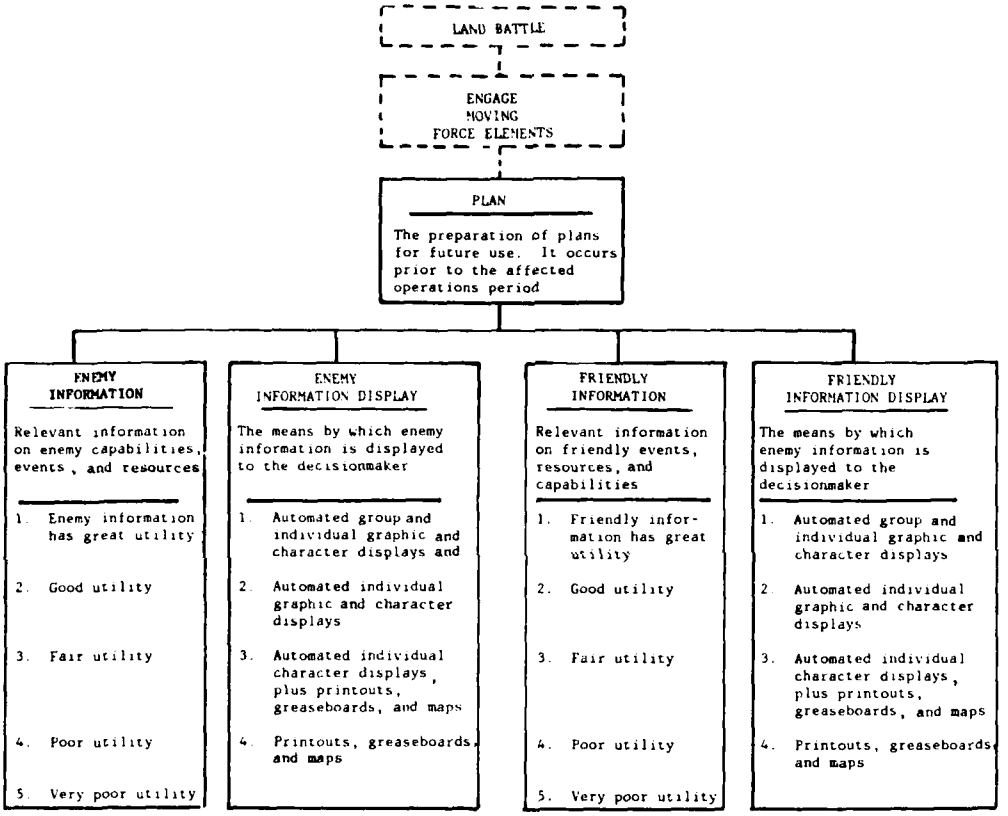

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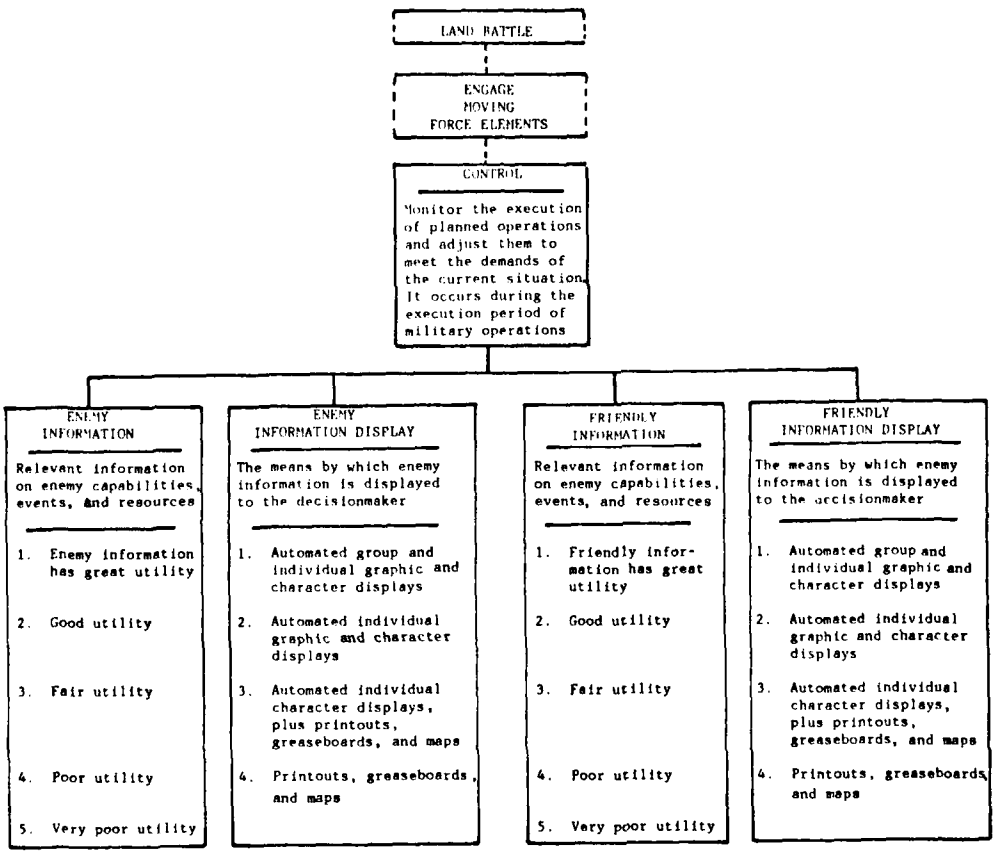

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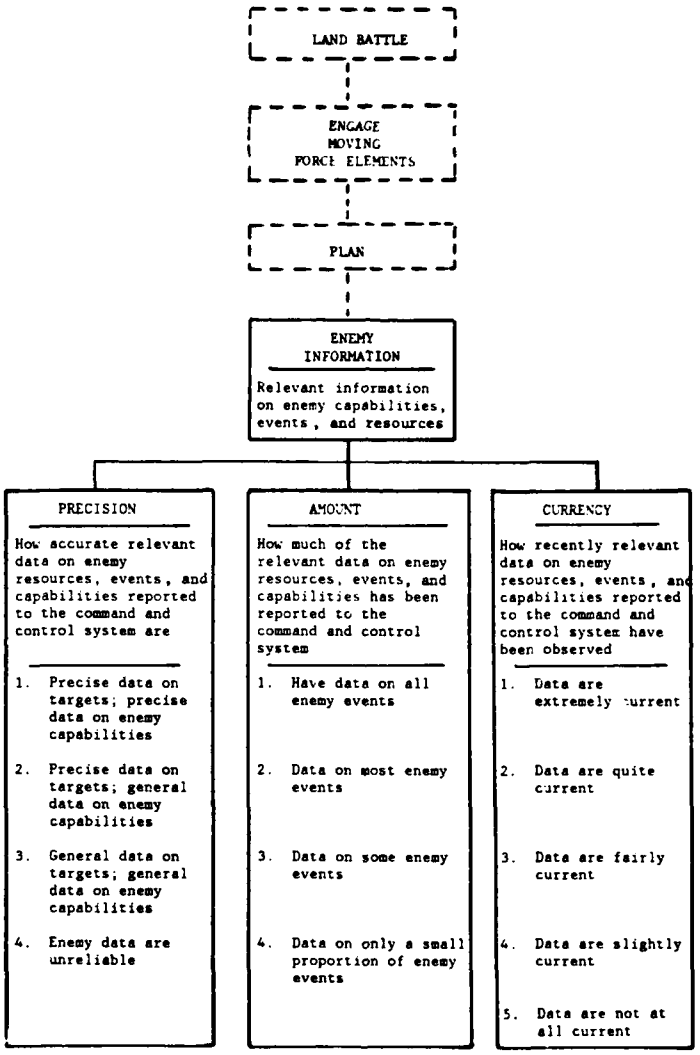

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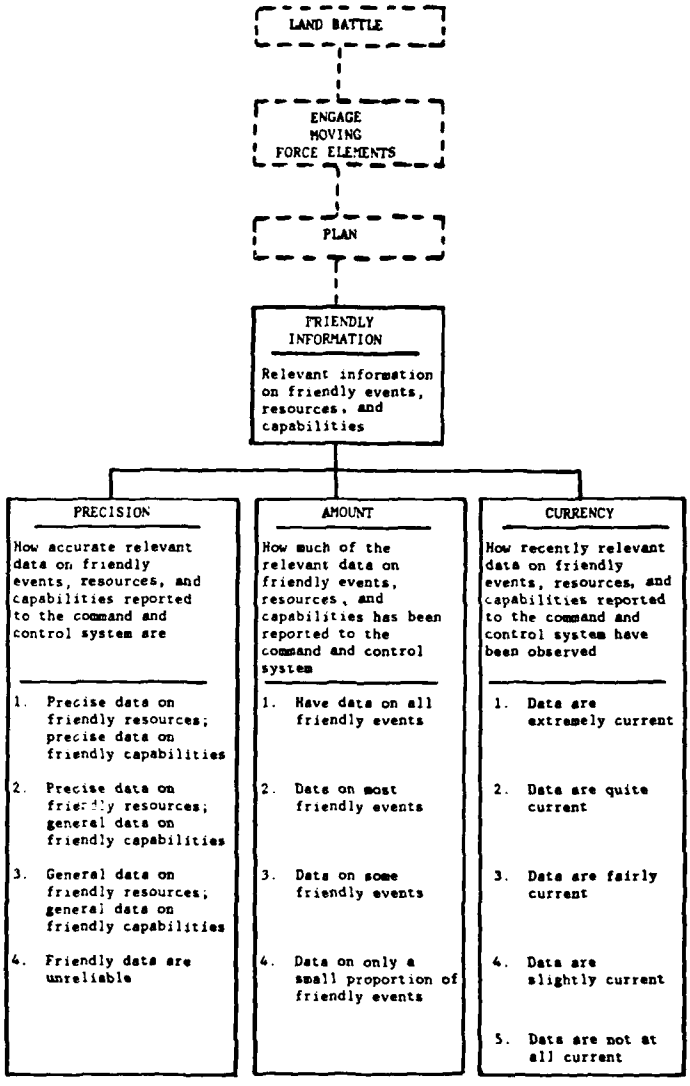

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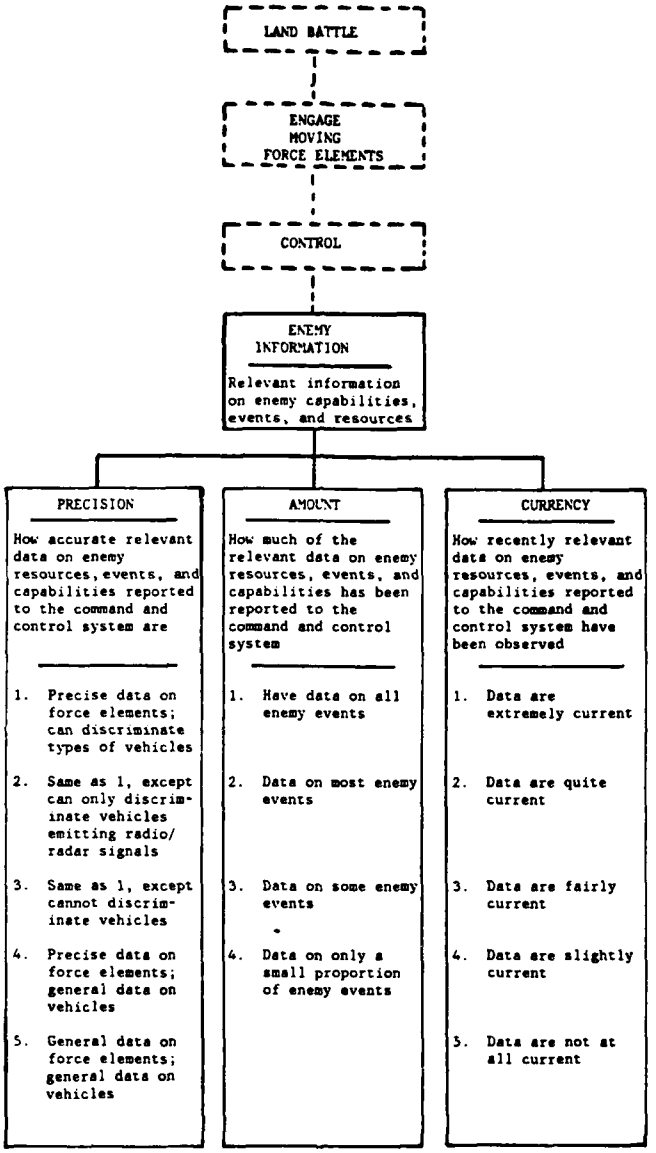

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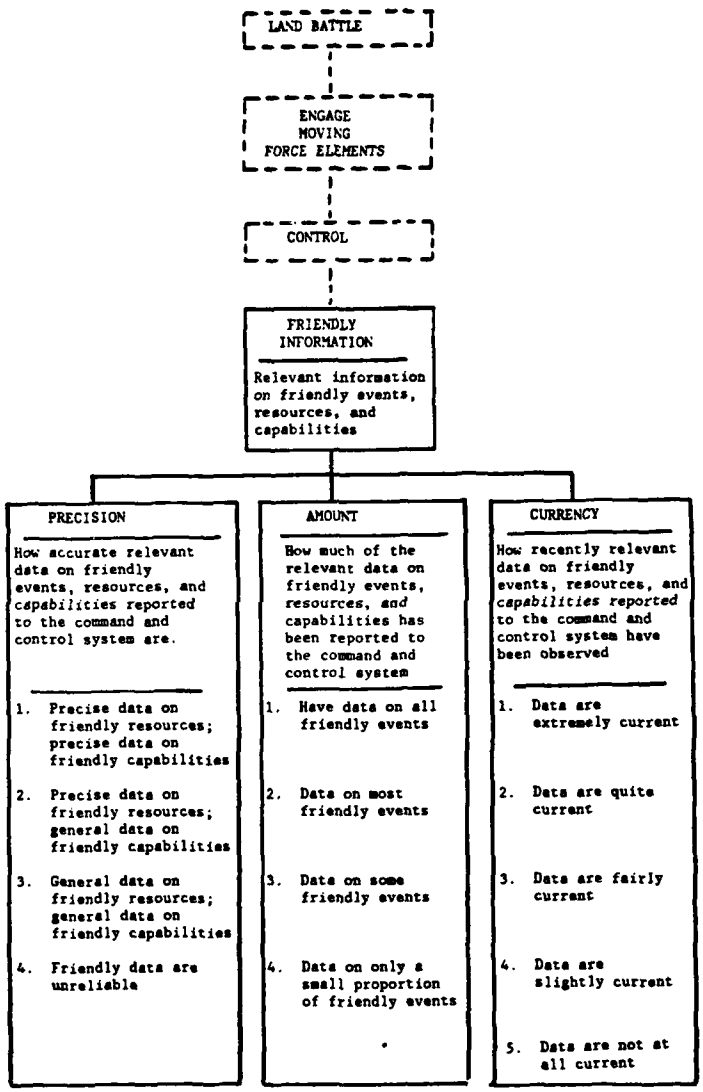

Fig. 23--Experimental Unit 36

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